Research Paper | Education | E-ISSN No : 2454-9916 | Volume : 10 | Issue : 5 | May 2024

LOW FREQUENCY DIELECTRIC PROPERTIES OF AGRICULTURE SOIL CONTAMINATED BY POTASH CHEMICAL FERTILIZERS

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ABSTRACT

Present paper investigates the impact of potash (KCl) contamination on the low-frequency (100 Hz - 1 MHz) dielectric properties of agricultural soil from the western Dhule district, India. Soil samples were spiked with varied KCl concentrations (0, 5, 10, and 20 mg) and analyzed using an LCR meter to measure dielectric constant, impedance, dielectric loss, and admittance. Results demonstrate a proportional increase in dielectric constant with increasing KCl concentration, indicating enhanced polarization within the soil matrix. Conversely, impedance and admittance displayed opposite trends, with impedance decreasing and admittance increasing as KCl concentration rose. Dielectric loss also exhibited a positive correlation with KCl content. This comprehensive investigation sheds light on the dynamic interplay between soil composition and dielectric properties under varying potash concentrations, contributing valuable insights to agricultural and environmental sciences.

KEYWORDS: Potash Contamination, Agricultural Soil, Low-Frequency Dielectric Analysis (LFDA), Dielectric Constant, Impedance, Admittance, Dielectric Loss, LCR Meter ,Dhule District

INTRODUCTION

Agriculture, with its allied sectors, is unquestionably the largest livelihood provider in India, more so in the vast rural areas. It also contributes a significant figure to the Gross Domestic Product (GDP). Sustainable agriculture, in terms of food security, rural employment, and environmentally sustainable technologies such as soil conservation, sustainable natural resource management and biodiversity protection, are essential for holistic rural development. Indian agriculture and allied activities have witnessed a green revolution, a white revolution, a yellow revolution and a blue revolution.

Agricultural soil is a dynamic and complex system. Understanding the health and integrity of agricultural soil is paramount for ensuring sustainable food production .Soil contamination by various pollutants, including salts and fertilizers, threatens this delicate ecosystem, impacting soil fertility, plant growth, and ultimately, food security. The nitrogen (N) applied to agricultural land (via synthetic fertilizers, composts, manures, bio solids, etc.) can provide valuable plant nutrients. However, if not managed correctly, excess N can have negative environmental consequences. Excess N supplied by both synthetic fertilizers (as highly soluble nitrate) and organic sources such as manures (whose organic N is mineralized to nitrate by soil microorganisms) can lead to groundwater contamination of nitrate. Nitrate-contaminated drinking water can cause blue baby syndrome. Potassium (K) play important role in plant metabolism. It is essential for optimum plant growth (White and Karley, 2010). There is a strong interaction between Nitrogen (N) and Potassium (K) (Rufty et al. 1981; Coskun et al. 2016) . Potash (KCl) plays a complex role regarding to soil health. While essential for plant nutrition, excessive potash application can lead to soil salinization, altering ionic balance and compromising microbial activity

It is (Ruan et al., 1998; Ruiz and Romero, 2002). Hu et al. (2016) reported that K deficiency can lead to some nitrate compounds. Excess of K also leads to unhealthy growth of plants as it affect the absorption of other critical nutrients. Consequently, monitoring potash levels in agricultural soils is crucial for optimizing fertilization practices and minimizing detrimental environmental impacts.

Traditional methods for assessing soil contamination often involve invasive, time-consuming, and resource-intensive laboratory analyses. This presents a significant challenge, particularly for large-scale agricultural monitoring where rapid and affordable solutions are critical. Recent advancements in low-frequency dielectric analysis (LFDA) offer a promising alternative. This non-destructive technique measures the electrical properties of materials, revealing valuable insights into their composition and structural characteristics.

The present study explores the potential of LFDA for quantifying potash contamination in agricultural soils. Focusing on samples collected from the western Dhule district in India, a region with intensive agricultural practices, we investigate the relationship between KCl concentration (0, 5, 10, and 20 mg) and key dielectric parameters: dielectric constant, impedance, dielectric loss, and admittance. Many researchers carried out experiments to study dielectric constant at microwave frequency (Chaudhari P. R. et al.2014). Very little details are available for low frequencies. The aim of this paper is to fill the gap in research at low frequencies.

MATERIALS AND METHODS

In the course of this research, soil samples were meticulously gathered from various locations within the depth range of 6 to 9 inches in SakriTahsil of Dhule district, Maharashtra. Adhering to established protocols, the soil underwent thorough mixing and was subsequently filtered using a 425-micrometer test sieve to ensure a homogeneous particle distribution. For experimentation, soil samples weighing 1.5 grams each were supplemented with varying proportions of murate of potash (KCl), specifically 0 mg, 5 mg, 10 mg, and 20 mg. Hydraulic compression, employing a 10-ton press, was employed to form sample pallets with a fixed diameter of 20 mm, ensuring a uniformity in width exceeding 2 mm.

Following the pallet formation, all samples underwent a drying process in an oven at 115°C to eliminate moisture, adhering to standard procedures. In the current study, the Wyne Kerr LCR meter from the 4100 series played a pivotal role in measuring capacitance (Cd), dielectric loss, impedance and admittance within the test soil serving as a dielectric medium. The frequency range for these measurements spanned from 100 Hz to 1 MHz. To establish a baseline, the capacitance with air as the dielectric medium (Ca) was calculated using the formula $Ca = \varepsilon o\, A / d$, where εo represents the permittivity of free space, A denotes the area, and d signifies the distance between the capacitor plates. The dielectric constant (K) for each frequency was subsequently computed as $K = Cd / Ca$. Calibration processes, including open circuit and short circuit calibrations, were rigorously implemented to minimize errors in the measurements.

RESULTS AND DISCUSSION

Dielectric constant:

At low frequencies, the ions in the KCl have ample time to respond to the applied electric field, contributing significantly to the overall conductivity. This, in turn, translates to a higher dielectric constant. As the KCl concentration increases, more ions are present, further amplifying this effect.

However, as the frequency ramps up,the sluggish movement of ions struggles to keep pace with the rapidly oscillating electric field. This results in a decreased current conduction, ultimately pulling the dielectric constant down. This phenomenon is particularly evident at frequencies exceeding 1000 Hz, where the ionic response becomes sluggish compared to the rapid field changes.

At higher frequencies, the dielectric constant exhibits less pronounced variations with KCl concentration. This is because the ionic contributions become negligible compared to the intrinsic polarization mechanisms of the soil itself. These mechanisms, independent of KCl concentration, dominate the dielectric response at higher frequencies, leading to the observed plateau effect.

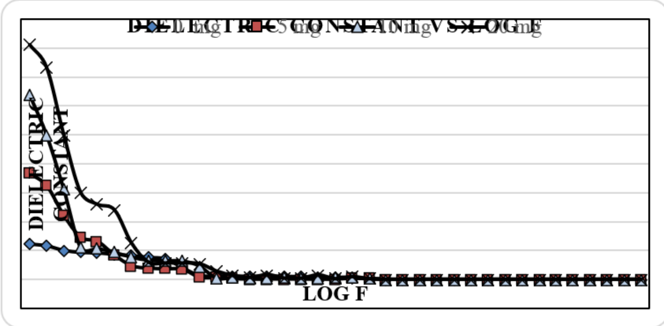

Fig. 1. Dielectric constant verses log of applied frequency

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Dielectric loss:

In the investigation of dielectric loss were explored across a frequency range from 100 Hz to 1 MHz. Remarkably, a consistent pattern emerged, revealing that dielectric loss remained relatively low up to 40 KHz. This suggests minimal ionic conduction at low frequencies. Ions have ample time to follow the electric field, resulting in low energy dissipation. Adding KCl initially introduces more conductive ions, but their sluggish movement at low frequencies limits their contribution to energy loss.As the frequency increased, there was a progressive rise in dielectric loss, peaking within a specific frequency range, followed by a subsequent decline. As frequency rises, ions are challenged to keep pace with the rapidly oscillating field. This increased friction, due to ionic lag, translates to higher energy dissipation and peak dielectric loss. At these frequencies, increasing KCl concentration provides more targets for the electric field, leading to more collisions and greater energy loss. However, the KCl-dependent rise in conductivity is still outweighed by the overall decrease in ion mobility at higher frequencies.Intriguingly, with an augmentation in KCl concentration, an overall reduction in dielectric loss occurred. This trend persisted, even at lower dielectric loss values, underscoring a complex interplay between frequency and KCl concentration.

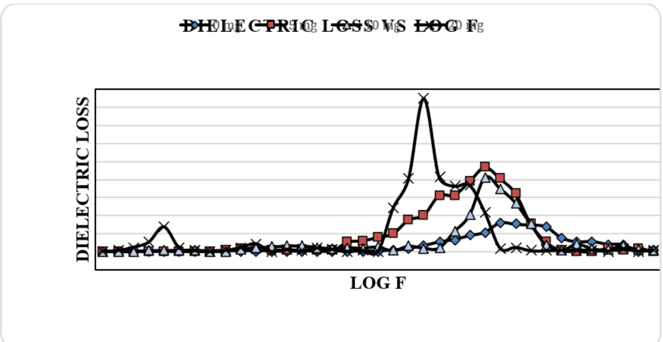

Fig. 2. Dielectric loss verses log of applied frequency

Impedance:

The observed trend in impedance measurements for varying concentrations of KCl in soil reveals intriguing insights into the electrical properties of the soil-KCl system. At lower

frequencies (up to 40 K Hz), the impedance is lower, indicating enhanced conductivity or capacitive effects within the soil. As the frequency increases, the impedance rises, suggesting a shift towards more resistive behavior. The decrease in impedance with increasing KCl concentration implies a potential augmentation in the soil's capacitive properties. Adding KCl introduces more conductive pathways, further lowering the impedance. Increased ionic mobility facilitates easier current flow. Interestingly, this trend persists at lower KCL concentration values, signifying a robust correlation between KCl concentration and electrical response. These findings may be attributed to the influence of KCl on soil conductivity and capacitive characteristics, shedding light on the intricate interplay between soil composition and electrical behavior across a broad frequency spectrum.

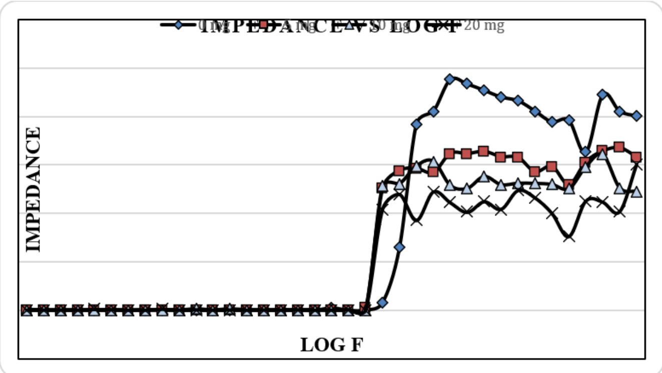

Fig. 3. Impedance verses log of applied frequency

Admittance:

The investigation of admittance across varying concentrations of KCl yields intriguing observations. Notably, a decline in admittance beyond 40 K Hz implies an increasing capacitive or resistive nature of the soil-KCl system at higher frequencies. Conversely, the rise in admittance at lower frequencies suggests enhanced conductivity or inductive effects within the system. The positive correlation between KCl concentration and admittance indicates a pronounced impact on the electrical behavior of the soil. Furthermore, the repetition of these trends at higher concentration of KCL accentuates the significance of KCl in influencing the electrical response of the soil across a broad frequency range. These findings contribute to a nuanced understanding of the intricate interplay between soil composition, KCl concentration, and electrical characteristics.

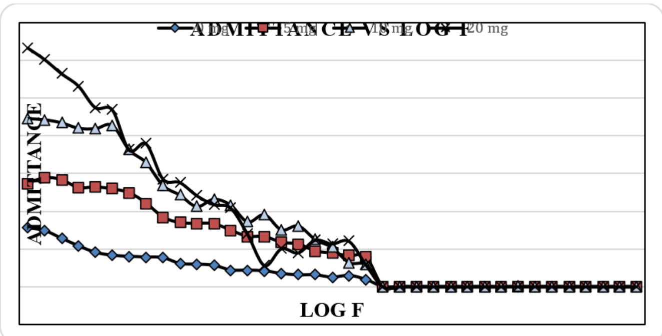

Fig. 4. Admittance verses log of applied frequency

CONCLUSION:

In conclusion, the comprehensive study on the electrical properties of soil samples with varying concentrations of KCl, conducted across a frequency range from 100 Hz to 1 M Hz, reveals intriguing patterns in dielectric constant, dielectric loss, impedance, and admittance. The dielectric constant exhibits an increase with KCl concentration at lower frequencies (up to 1000 Hz), attributed to enhanced conductivity. However, at higher frequencies, the dielectric constant decreases due to reduced current conduction. The dielectric loss, on the other hand, follows a more complex trend, initially low up to 40 K Hz, increasing with frequency, and then decreasing again. Higher concentrations of KCl correlate with lower dielectric loss, emphasizing its role in influencing electrical behavior. The impedance shows a similar pattern, being low up to 40 K Hz and increasing thereafter, while the admittance displays an increase with decreasing frequency and higher KCl concentrations. Overall, these findings underscore the intricate interplay between KCl concentration, frequency, and the electrical characteristics of soil, providing valuable insights for applications in fields such as agriculture and geophysics.These observation clearly indicates that the dielectric analysis of agriculture soil can be used to analyze the amount of chemical fertilizers present in soil. This method may reduce time and cost of testing.

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